EXECUTIVE SUMMARY

The Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE) leads the Federal Government's efforts to provide reliable, affordable, and environmentally sound energy for America, through its 11 research, development, demonstration, and deployment (RDD&D) programs. EERE invests in high-risk, high-value research and development (R&D) that, conducted in partnership with the private sector and other government agencies, accelerates the development and facilitates the deployment of advanced clean energy technologies and practices. EERE designs its RDD&D activities to improve the Nation's readiness for addressing future energy needs.

This document summarizes the results of the benefits analysis of EERE's programs, as described in the FY 2005 Budget Request. EERE has adopted a benefits framework developed by the National Research Council (NRC)[1] to represent the various types of benefits resulting from the energy efficiency technology improvements and renewable energy technology development prompted by EERE programs. Specifically, EERE's benefits analysis focuses on three main categories of energy-linked benefits—economic, environmental, and security. The specific measures or metrics of these benefits estimated for FY 2005 are identified in **Table ES.1**. These metrics are not a complete representation of the benefits or market roles of efficiency and renewable technologies, but provide an indication of the range of benefits provided. EERE has taken steps to more fully represent the NRC framework, including two key improvements to the FY 2005 analysis—adding an electricity security metric and extending the analysis through the year 2050. EERE will be implementing additional portions of the framework in the future.

Table ES.1. EERE FY 2005 Benefits Metrics

Primary Outcome	
Energy displaced	• Reductions in nonrenewable energy consumption
Resulting Benefits	
Economic	• Reductions in consumer energy expenditures (NEMS-GPRA05) • Reductions in energy-system costs (MARKAL-GPRA05)
Environmental	• Reductions in carbon dioxide emissions
Security	• Reductions in oil consumption • Reductions in natural gas consumption • Avoided additions to central conventional power[2]

Table ES.2 shows the estimated energy displaced and resulting benefits to the Nation of realizing the EERE program goals associated with the FY 2005 budget request. These impacts are the benefits expected in the reported year—that is, the benefits are annual, not cumulative. Under a business-as-usual energy future, realization of these goals and the associated projected market outcomes would:

[1] *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, National Research Council (2001). The NRC is the principal operating agency of the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE), providing services to the government, the public, and the scientific and engineering communities.

[2] Central conventional power includes centrally located fossil, nuclear, combined cycle, combustion turbine/diesel, and pumped storage. It does not include distributed power and renewable power (central or distributed).

- Reduce the expected increase in U.S. energy demand by 31% in 2025 and 60% in 2050, resulting in a leveling off of nonrenewable energy consumption starting in 2025. (**Figure ES.1**)
- Reduce the expected increase in U.S. consumer energy expenditures by 37% in 2025. (**Figure ES.2**)
- Reduce the expected increase in U.S. energy system costs by 6% in 2050. (**Figure ES.3**)
- Reduce the expected increase in annual U.S. carbon dioxide emissions by 35% in 2025 and 54% in 2050. (**Figure ES.4.**)
- Reduce the expected increase in U.S. oil consumption (most of which is expected to originate from outside the United States) by 26% in 2025 and 84% in 2050, resulting in declining oil consumption after 2025. (**Figure ES.5**)
- Reduce the expected increase in U.S. natural gas consumption, much of which is expected to originate outside the United States, by 18% in 2025 and 21% in 2050. (**Figure ES.6**)
- Reduce the need for additions to central conventional power by 64% in 2025. (**Figure ES.7**)

Table ES.2. Summary of EERE Integrated Portfolio Benefits for FY 2005 Budget Request[34]

EERE Midterm Benefits	2010	2015	2020	2025
Energy Displaced				
• Nonrenewable energy savings (quadrillion Btu/yr)	1.8	3.6	6.9	10.4
Economic				
• Energy-expenditure savings (billion 2001 dollars/yr)*	27	51	90	134
Environment				
• Carbon dioxide emission reductions (mmtc equivalent/yr)	35	74	139	213
Security				
• Oil savings (mbpd)	0.2	0.5	1.1	2.1
• Natural gas savings (quadrillion Btu/yr)	0.7	1.0	1.9	1.9
• Avoided additions to central conventional power (gigawatts)[5]	24	66	105	157

EERE Long-Term Benefits	2020	2030	2040	2050
Energy Displaced				
• Nonrenewable energy savings (quadrillion Btu/yr)	7.4	16.5	25.8	32.3
Economic				
• Energy-system cost savings (billion 2001 dollars/yr)*	42	88	171	236
Environment				
• Carbon dioxide emission reductions (mmtc equivalent/yr)	145	334	471	593
Security				
• Oil savings (mbpd)	1.0	4.7	9.0	11.6
• Natural gas savings (quadrillion Btu/yr)	2.6	2.8	5.2	4.5

* Midterm energy-expenditure savings only include reductions in consumer energy bills, while long-term energy-system cost savings also include the incremental cost of the advanced energy technology purchased by the consumer.

[3] Estimates reflect the benefits associated with program activities from FY 2005 to the benefit year, or to program completion (whichever is nearer), and are based on program goals developed in alignment with assumptions in the president's budget. Midterm program benefits were estimated using the NEMS-GPRA05 model, based on the Energy Information Administration's (EIA) National Energy Modeling System (NEMS) and using the EIA's *Annual Energy Outlook 2003* (*AEO2003*) Reference Case. Long-term benefits were estimated using the MARKAL-GPRA05 model developed by Brookhaven National Laboratory. Results can differ among models due to structural differences. The models used in this analysis estimate economic benefits in different ways, with MARKAL reflecting the cost of additional investments required to achieve reductions in energy bills.

[4] For some metrics, the benefits estimated by MARKAL-GPRA05 do not align well with those reported by NEMS-GPRA05. Every attempt is made in the integrated modeling to use consistent baselines, input data and assumptions in both models to produce consistent results. However, NEMS and MARKAL are in some respects fundamentally different models (see Boxes 4.1 and 5.1). Discrepancies in the estimated benefits often differ simply because of these model differences.

[5] Small final changes in these estimates were not reflected in the FY 2005 Budget Request.

EERE develops these benefits projections annually to help meet the requirements of the Government Performance and Results Act (GPRA) of 1993 and the President's Management Agenda (PMA). GPRA requires Federal Government agencies to develop and report on output and outcome measures for each program. This analysis helps meet GPRA requirements by identifying the potential outcomes and benefits of realizing EERE program goals (outputs). The benefits estimates do not reflect the risk of realizing these goals, which is being addressed separately.[6]

The reported benefits reflect only the net annual improvement from 2005 to 2050 of program activities included in EERE's FY 2005 Budget Request (including subsequent-year funding) and do not include the benefits from past work. The benefits estimates assume continued funding for program activities consistent with multiyear program plans.[7] By basing estimated benefits on budget levels, the analysis addresses the performance-budget integration goal of the PMA. This analysis also provides the benefits called for in the R&D Investment Criteria, developed by the Office of Management and Budget (OMB) as part of the PMA.

EERE uses two energy-economy models—NEMS-GPRA05 and MARKAL-GPRA05—to estimate the impacts of EERE programs on energy markets. The NEMS-GPRA05 model is a modified version of the National Energy Modeling System (NEMS), the midterm energy model used by the Department of Energy's Energy Information Administration (EIA). The MARKAL-GPRA05 model is a modified version of the MARKet ALlocation (MARKAL) model developed by Brookhaven National Laboratory and used by numerous countries worldwide. EERE uses NEMS-GPRA05 to estimate the midterm benefits of its programs and MARKAL-GPRA05 to estimate the long-term benefits of its programs. Descriptions of these models are provided in **Chapters 4 and 5**.

EERE uses a three-step process to estimate benefits across its portfolio:

(1) Establishment of the Baseline Case and guidance
(2) Determination of program and market inputs
(3) Assessment of program and portfolio benefits.

In **Step 1**, a Baseline Case and standard methodological approach (guidance) are developed to improve the consistency of estimates across EERE programs. The Baseline Case provides a representation of business-as-usual future energy markets without the effect of EERE programs. It also provides a consistent set of assumptions about future energy prices, conversion factors, economic growth, and other external factors, against which to analyze the impacts of EERE programs. To develop the Baseline Case through 2025, EIA's *Annual Energy Outlook 2003* (*AEO2003*) Reference Case forecast is modified to remove any identifiable effects of EERE programs already included in the forecast. This is done for both the NEMS-GPRA05 model and the MARKAL-GPRA05 model.[8]

For the period after 2025, other credible sources are used to compile a set of economic and

[6] A standard approach to risk assessment is being developed for EERE's multiyear program plans.
[7] Funding levels may increase, decrease, or remain constant, depending on the program. See Appendices B through M for information on individual multiyear program plans.
[8] Slight differences in the NEMS-GPRA05 and MARKAL-GPRA05 baselines may occur from the differences inherent in the two models.

technical assumptions for MARKAL-GPRA05.[9] A summary of the Baseline Case results is included in **Appendix A**. EERE also specifies common methodological approaches (guidance) used in developing benefits estimates. This guidance identifies common definitions, the basis for assessing benefits, data requirements, etc. An overview is provided in **Chapter 2**.

In **Step 2**, analysts from throughout EERE characterize the results of the EERE programs in a format suitable for analysis within the NEMS and MARKAL integrated-modeling frameworks. For technology R&D programs, this usually requires expressing program outputs in terms of the cost and performance of a new (or improved) product, which will compete against an existing technology in the baseline. For deployment programs (*e.g.*, information dissemination, or codes and standards), analysts develop approaches to characterizing outputs on a case-by-case-basis using alternative modeling techniques such as altering discount rates or fixing market penetration (in the case of minimum efficiency standards). In many cases, the NEMS and MARKAL frameworks are not suitable for directly analyzing programmatic activities; as a result, "off-line" analyses are conducted. The market analyses and off-line estimates used in the integrated modeling framework are documented in **Appendices B through M.**

In **Step 3**, the program- and market-specific information from **Step 2** is incorporated into NEMS-GPRA05 and MARKAL-GPRA05. Modeling all the programs together accounts for market feedbacks and interactions that can change the ultimate level of energy savings associated with realizing each program's goals. EERE adjusts off-line estimates to account for areas of overlapping program impacts. This downward revision is based on how much of the overlap or integration was captured by the off-line analysis. The benefits analysis team, based on its expert judgment, determines the amount of revision. The resulting benefits estimates of individual program analyses are listed by program, along with FY 2005 program budgets, in **Table ES.3** below.

Analysts also run NEMS-GPRA05 and MARKAL-GPRA05 with all programs simultaneously represented, in order to derive estimates of the benefits of the overall EERE portfolio. This portfolio analysis accounts for interactions among EERE's programs, and tends to report reduced benefits compared to the sum of the individual programs. These fully integrated results are listed in **Table ES.2** and displayed in the graphs in this **Executive Summary**. Specific details on the representation of program outputs in NEMS-GPRA05 and the underlying program analysis and documentation are provided in **Chapter 4** of this report. Representation of the program outputs in MARKAL-GPRA05 is provided in **Chapter 5**.

EERE is pursuing a number of improvements to its benefits analysis. Important changes planned for analysis of the benefits of the FY 2006 budget request include:

- Developing alternative scenarios that reflect potential options facing the Nation in the future (*e.g.*, higher fossil fuel prices, a carbon-constrained world).
- Greater streamlining and consistency in the development of program-level benefits estimates.

[9] For instance, the primary economic drivers of Gross Domestic Product (GDP) and population are based on the real GDP growth rate from the Congressional Budget Office's Long-Term Budget Outlook and population growth rates from the Social Security Administration's *2002 Annual Report* to the board of trustees.

In addition, EERE is developing methods for linking estimates of benefits from both past and future program efforts into the overarching NRC benefits framework noted above. Finally, EERE is developing a more systematic way of representing program and technology risk. Although not part of this benefits analysis *per se*, information on risk is recognized as an important component in the application of benefits information to portfolio management.

Table ES.3. U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE): FY 2005 Funding Summary and Selected 2025 and 2050 Benefits by Program[10]

Program	FY 2005 Request (thousands $)	Nonrenewable Energy Displaced (quads/yr)		Energy Expenditure Savings (billions 2001$/yr)		Energy System Cost Savings (billions 2001$/yr)		Carbon Dioxide Emissions Reductions (million Mtce/yr)		Oil-Use Reductions (mbpd)	
		2025	2050	2025	2050	2025	2050	2025	2050	2025	2050
Biomass	81,276	0.2	1.2	1.7	N/A	N/A	-0.3	2.7	22.6	0.0	0.4
Building Technologies	58,284	2.0	2.8	26.6	N/A	N/A	45.3	42.5	49.8	0.1	0.2
Distributed Energy Resources	53,080	0.4	1.2	10.6	N/A	N/A	6.2	15.2	30.1	0.0	0.0
Federal Energy Management	19,867	0.1	0.2	0.6	N/A	N/A	3.0	1.5	4.0	0.0	0.0
Geothermal Technologies	25,800	0.3	2.1	1.5	N/A	N/A	8.9	6.7	49.9	0.0	0.0
Hydrogen, Fuel Cells, and Infrastructure Technologies	172,825	0.5	9.2	5.2	N/A	N/A	78.6	11.8	138.3	0.4	6.2
Industrial Technologies	58,102	2.0	2.2	15.8	N/A	N/A	15.0	41.4	40.8	0.2	0.1
Solar Energy Technologies	80,333	0.4	1.6	4.9	N/A	N/A	0.3	9.0	28.9	0.0	0.0
Vehicle Technologies[11]	156,656	2.9	16.2	55.5	N/A	N/A	150.1	54.0	316.8	1.4	7.6
Weatherization and Intergovernmental	380,067	1.1	0.5	16.8	N/A	N/A	5.4	24.3	12.3	0.1	0.3
Wind and Hydropower	47,600	1.8	4.2	3.9	N/A	N/A	7.6	38.9	87.8	0.0	0.0
National Climate Change Technology Initiative	3,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Facilities and Infrastructure	11,480	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Program Direction	102,375	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sum of programs **	**1,250,745**	**11.7**	**41.4**	**142.9**	**N/A**	**N/A**	**320.2**	**247.9**	**781.2**	**2.2**	**14.8**

** The sum of program benefits differs from the EERE portfolio values in Table ES.2, because interactions among programs are not accounted for in the individual estimates. Sums may not total due to rounding.

[10] Budget request from *FY 2005 Budget-in-Brief*, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy05_budget_in_brief.pdf.

[11] The Vehicle Technologies Program is run by the Office of FreedomCAR and Vehicle Technologies.

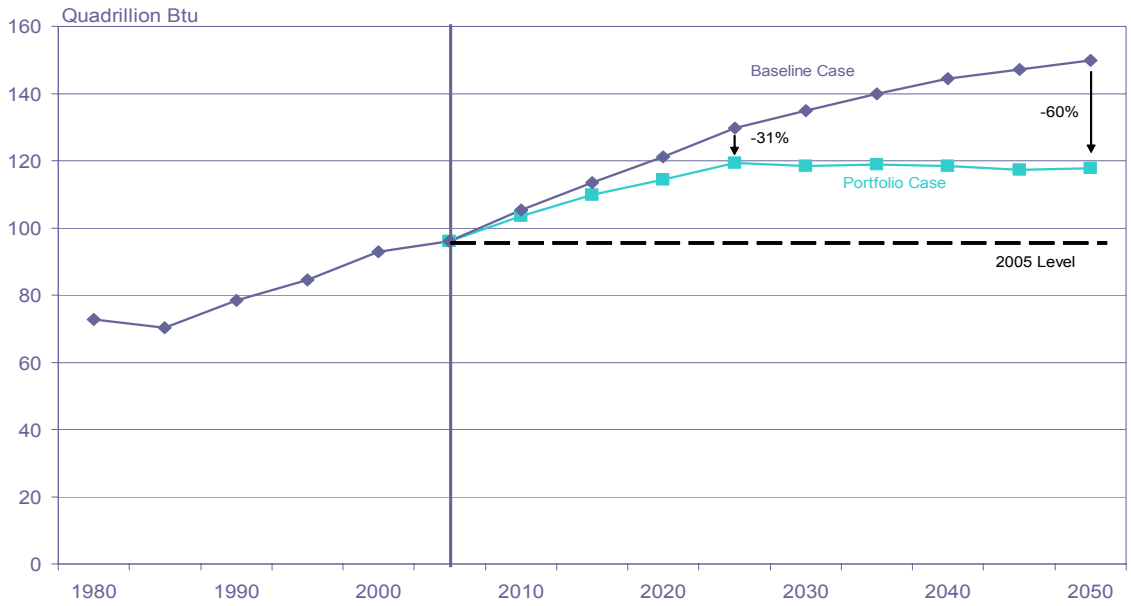

Figure ES.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2002*, DOE/EIA-0384 (2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025: NEMS-GPRA05; 2030-2050: MARKAL-GPRA05.

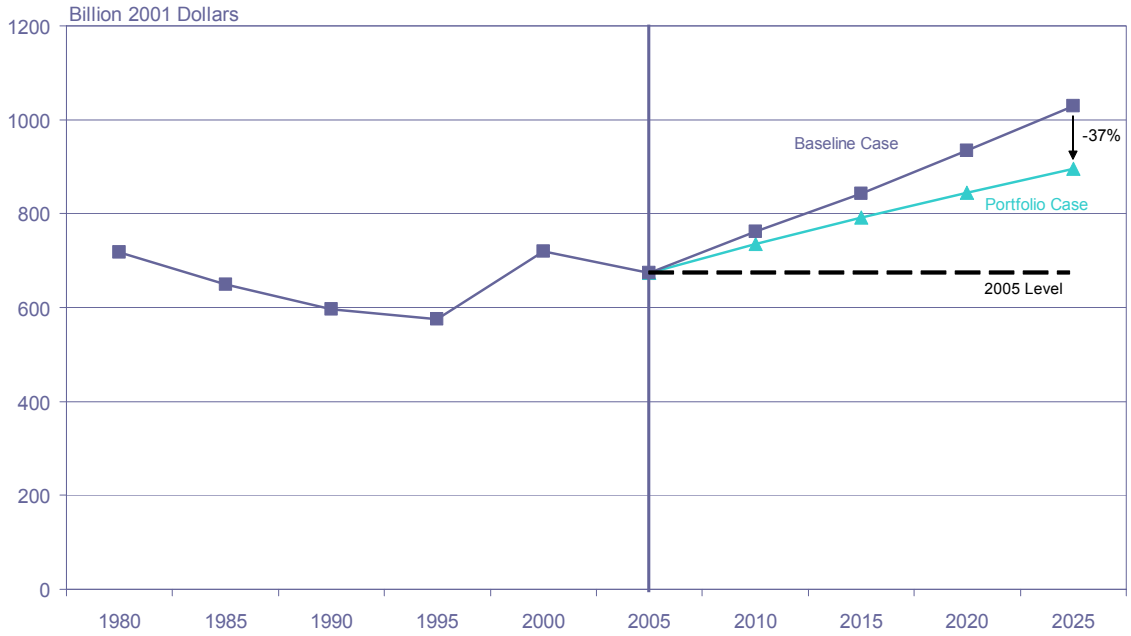

Figure ES.2. U.S. Total Energy Expenditures, 1980-2000, and Projections to 2025: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2002*, DOE/EIA-0384 (2002), Table 3.4 and Table D1, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025: NEMS-GPRA05; 2030-2050: MARKAL-GPRA05.

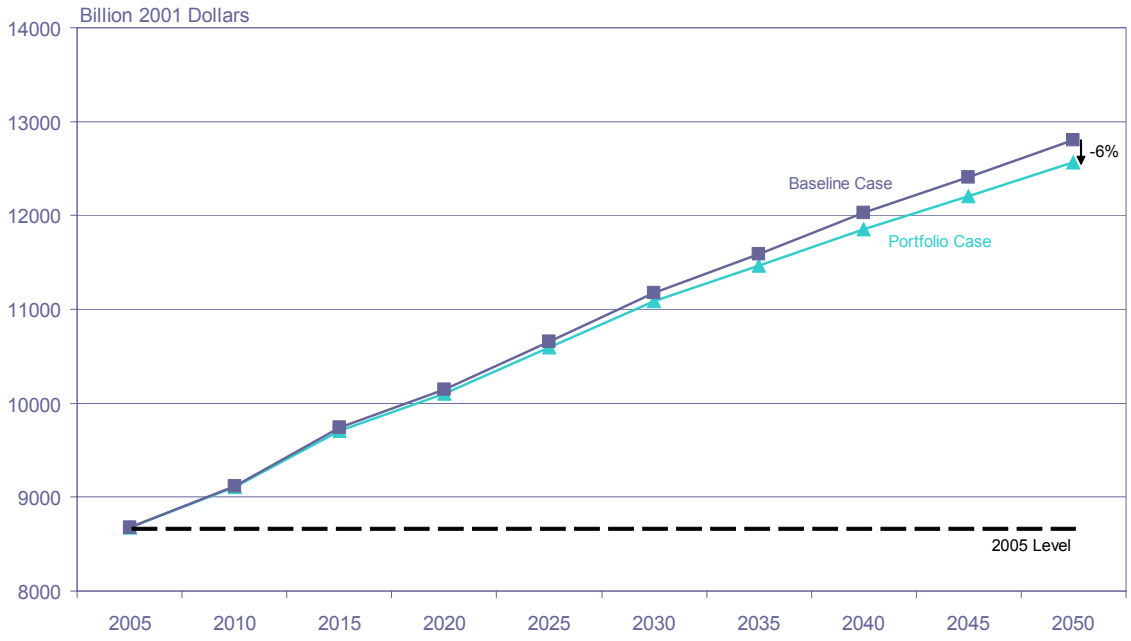

Figure ES.3. U.S. Total Energy-System Cost Projections to 2050: Portfolio Case

Note: The percentage change in the chart shown for 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2050 versus 2005. Data Source: MARKAL-GPRA05.

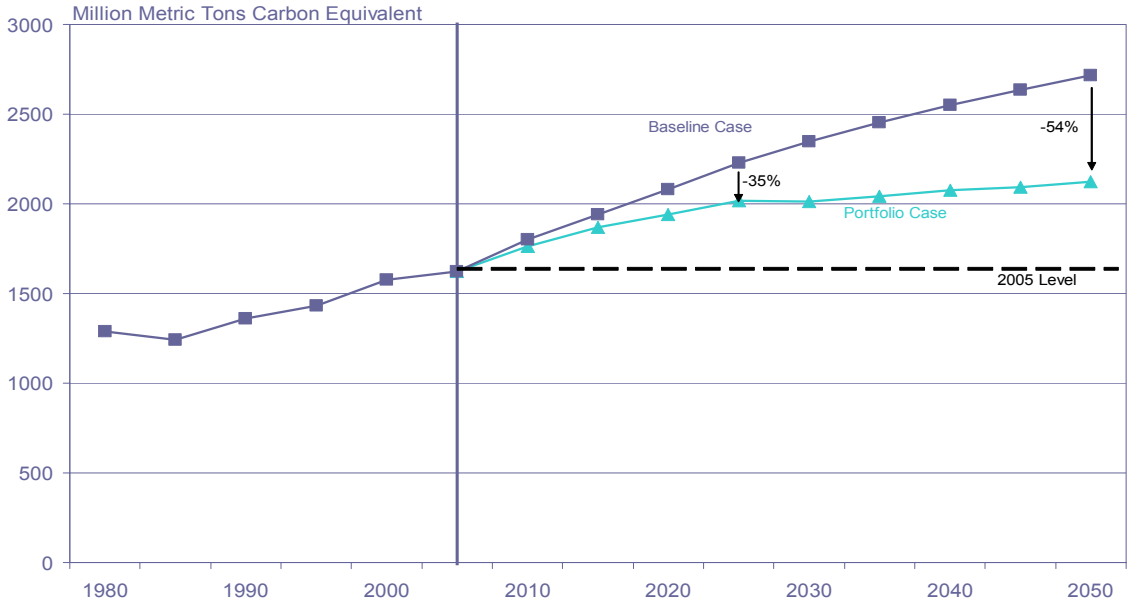

Figure ES.4. U.S. Carbon Dioxide Emissions, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2002*, DOE/EIA-0384 (2002), Table 12.2, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA05; 2030-2050, MARKAL-GPRA05.

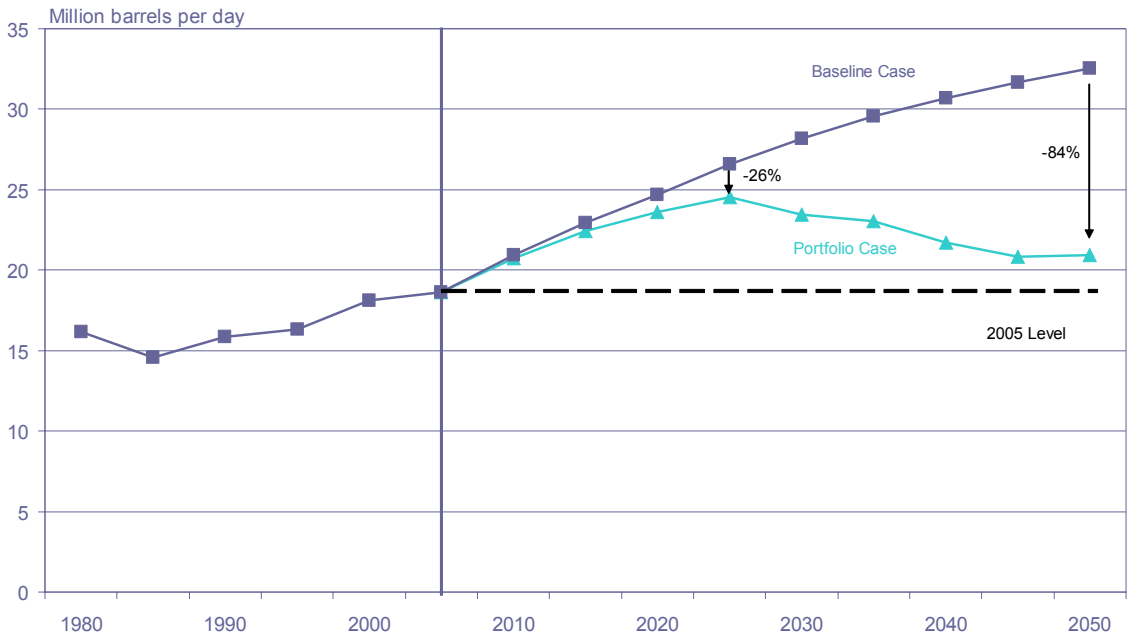

Figure ES.5. U.S. Oil Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, EIA, *Annual Energy Review 2002*, DOE/EIA-0384 (2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA05; 2030-2050, MARKAL-GPRA05.

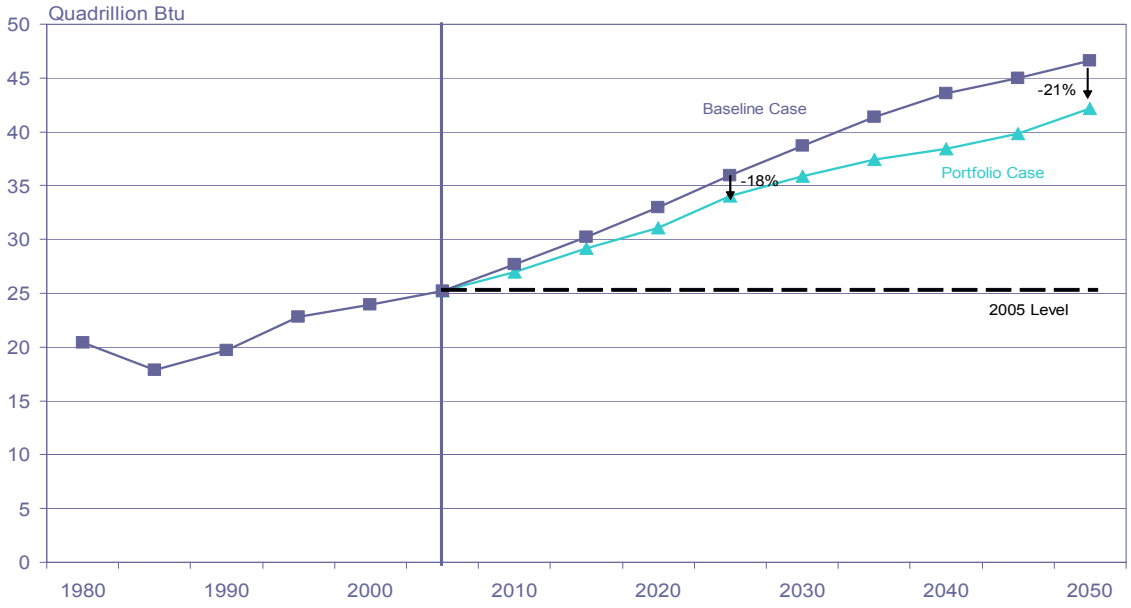

Figure ES.6. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Data Sources: 1980-2000, EIA, *Annual Energy Review 2002*, DOE/EIA-0384 (2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA05; 2030-2050, MARKAL-GPRA05.

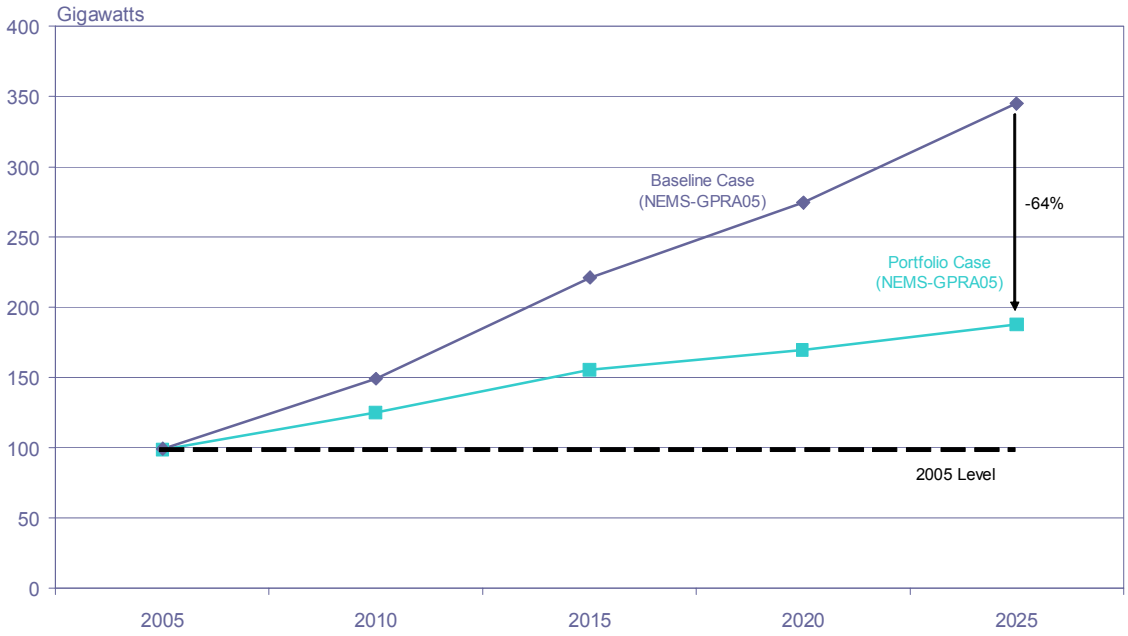

Figure ES.7. U.S. Central Conventional Electricity-Capacity Addition Projections to 2025: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 versus 2005. Data Source, NEMS-GPRA05.